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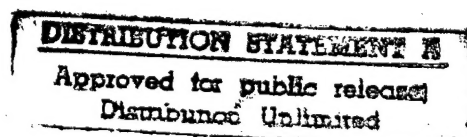
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**FEDERAL FUNDING OF CIVILIAN
RESEARCH AND DEVELOPMENT —
VOLUME 1: SUMMARY**

Arthur D. Little, Inc.
1735 Eye Street, N. W.
Washington, D. C. 20006

February 1976

Final Report
Contract 4-35956

Prepared for
Experimental Technology Incentives Program



U.S. DEPARTMENT OF COMMERCE, Elliot L. Richardson, *Secretary*

James A. Baker, III, *Under Secretary*

Dr. Betsy Ancker-Johnson, *Assistant Secretary for Science and Technology*

NATIONAL BUREAU OF STANDARDS, Ernest Ambler, *Acting Director*

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<p>16. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)</p> <p>As a part of its program with respect to the funding of civilian research and development by the Federal Government, the Experimental Technology Incentives Program of the National Bureau of Standards awarded a contract to Arthur D. Little, Inc. to conduct a study whose purpose was "To better understand how federal funding of civilian research and development has functioned as an agent of technological change in the private sector.</p> <p>The fundamental conclusion reached in the study was "Federally-funded civilian research and development is not sufficient to bring about technological change in the private sector to any significant extent." This is true because R&D cost is a small part of the total cost of bringing technological innovation into the marketplace. The study finds that this fact is often overlooked by federal policy makers in both the Executive and Legislative Branches. It is cited as one of the reasons why many United States companies with proven records of developing and marketing new products often shun federal R&D funds, and why so many federal R&D projects are shelved.</p> <p>The authors suggest that the results of the study indicate that federal funding of civilian R&D should be formulated in the larger context of the complex process of technological innovation.</p> <p>This volume provides a summary of the study.</p>			
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Dr. Jordan Lewis
Director
Experimental Technology Incentives Program
U.S. Department of Commerce
National Bureau of Standards
Washington, D.C. 20234

Dear Dr. Lewis:

We are pleased to submit Volume 1: "Summary" on our study of
"Federal Funding of Civilian Research and Development." Volume 2:
"Case Studies" is bound and submitted separately.

The results of our work suggest that federal funding of civilian R&D should be formulated in the larger context of the complex process of technological innovation. This means that complementary public policy measures need to be developed and implemented so as to create a climate that stimulates greater risk-taking by the private sector in pursuit of technological innovation. Implied in this suggestion is an important but relatively unknown ingredient, namely that of knowing which federal policies and procedures are and which are not consistent with achieving this goal.

We believe that the Experimental Technology Incentives Program is supporting imaginative studies and experiments to illuminate these issues. We are particularly pleased to have had this opportunity of undertaking for you this first study concerned with the effectiveness of federal R&D funding. We are glad to know that further work will be supported by your office in this area, and we wish you every success.

We want to take this opportunity of expressing our deep appreciation to you and your staff, to our Advisory Committee for this study, to the three experts you selected to provide independent critiques of our draft report, and to the numerous individuals in government and industry, all of whom gave generously of their time and experience

Arthur D Little, Inc.

Dr. Jordan Lewis
Director
Experimental Technology Incentives Program
U.S. Department of Commerce

to aid us in this undertaking. Their names, where we were permitted to identify them, appear at appropriate places in both volumes of our report.

Sincerely yours,

Michael Michaelis

Michael Michaelis

mm/ems

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EXECUTIVE SUMMARY

*Federally-Funded Civilian Research and Development is Not Sufficient to Bring About Technological Change in the Private Sector to Any Significant Extent.**

This is the fundamental conclusion reached in this study.

Countless examples show that R&D cost is a small part of the total cost of bringing technological innovation into the marketplace. This fact is often overlooked by federal policy makers in both the executive and legislative branches. It is one of the reasons why many U.S. companies with proven records of developing and marketing new products often shun federal R&D funds, and why so many federal R&D products are shelved.

The "mythology" of federal R&D is derived largely from the success stories of the Manhattan- and Apollo-type projects. What is too often overlooked is that in such instances the government was not only the funder of R&D, but it was also the customer for the resulting hardware and systems.

Now the government's role as consumer is diminishing for a growing fraction of the R&D it funds. R&D targeted to the civilian sector has increased from 23% to 35% in the last six years. The new consumers are industry, local government, and private citizens. In these instances, the funder of R&D, the performer of R&D, the manufacturer using R&D-generated knowledge, and the customers are separate and autonomous elements related through the workings of the market.

Government intervention in the marketplace may be called for when deficiencies in its workings are detrimental to the economic or social well-being of the country. Merely funding civilian R&D is insufficient to correct those situations.

We found that successful commercialization of federally-funded R&D is nearly always accompanied by public policy measures that cause or stimulate market demand. Technological innovation is most often *pulled* into the marketplace through appropriate incentives rather than *pushed* by federally-funded R&D.

Therefore:

Policies for Federal Funding of Civilian R&D Should be Formulated in the Larger Context of the Complex Process of Innovation.

*In the context of this project, "Civilian R&D" is defined as those technical activities which can function as stimulants for technological change, to be brought about by private industry acting as the change agent, and resulting in technologically innovative products and processes being introduced into the civilian marketplace.

I. OVERVIEW

A. PURPOSE

Management of federally funded civilian R&D poses one of the major science and technology policy issues of this decade. Attempts to examine these issues systematically have been carried out in the past, but those efforts received relatively little attention.* The stakes are now much larger and the hour is late.

The primary purpose of this study was:

To Better Understand How Federal Funding of Civilian Research and Development has Functioned as an Agent of Technological Change in the Private Sector.

This report is a policy history, based on the following six tasks:

- Task 1: Determine where in the federal hierarchy policies for the funding of civilian R&D originate.
- Task 2: Characterize the explicit and implicit policies used to allocate funds for civilian R&D.
- Task 3: Define the explicit or implicit objectives of federal civilian R&D funding.
- Task 4: Identify alternatives to R&D funding which could have achieved the same objectives, and determine whether they were considered by the funding agency(ies).
- Task 5: Assess the relative efficiency of federal R&D funding in accomplishing stated objectives.
- Task 6: Assess the efficiency of federal policies toward the support of civilian R&D.

*For instance:

- "White House Civilian Technology Panel," 1961-1963
- "Criteria for Federal Support of Research Development," U.S. Chamber of Commerce, 1965
- "Technological Innovation: Its Environment and Management," U.S. Department of Commerce, 1967.

Six federal R&D programs were chosen as case studies for our research and analysis:

1. Central Station Nuclear Power
2. Coal Extraction and Conversion
3. Motor Vehicle Safety
4. Urban Mass Transportation
5. Edible Soy-Protein
6. Biological Pesticides

Our findings and the rationale for them, along with supporting material, are summarized in this Volume One. The detailed analyses of these six programs, are presented in Volume Two: "Case Studies."

This study was carried out between July 1974 and December 1975. The principal participants are listed in Appendix A.

B. FINDINGS

Federal R&D policies have been mainly the result of decentralized decision-making by mission-oriented departments and agencies. True, these policies are often responses to national contingencies and political imperatives (e.g., the energy crisis, or Presidential or Congressional mandates), but they reflect internal interpretations of the agency's mission and bear the imprint of the agency's current interests and budget considerations, responsive to overall Presidential (OMB) mission directives and to likely Congressional reaction and vested-interest pressures.

In Central Station Nuclear Power, Urban Mass Transportation, and Motor Vehicle Safety, we found explicit objectives for federally-funded R&D to include the aiding of commercializing of technical knowledge derived from R&D. Public policy measures (in addition to R&D funding) were either legislated or carried out through Executive Order to stimulate commercialization. In most instances, such measures provided financial incentives of various kinds, designed to help overcome specific barriers to commercialization. These included capital grants (e.g., in Urban Mass Transportation), provision of federally-funded services (e.g., uranium enrichment for nuclear fuel), or federally-mandated regulations (e.g., for passenger protection — seat belts, etc. — in motor vehicles).

In Coal Extraction and Conversion, Edible Soy-Protein, and Biological Pesticides, commercialization was not an explicit objective of federal R&D funding. To be sure, federal policy-makers hoped that the marketplace would "pull" the technical knowledge into commercial practice, but no consideration was given to government action in addition to funding of R&D to bring this about. Moreover, there was minimal interaction between the R&D funding agency and potential industry users of the technical knowledge to be derived from the R&D, particularly regarding directions, priorities, time-scales, and intensity of R&D funding, as well as any additional public policy measures needed to stimulate commercialization of the R&D results.

In all six research areas we found that the process of innovation,* involving the private sector as the agent for change, was poorly understood by the federal R&D funding agency.

The innovative process is often not a linear, point-to-point process, in which each step is part of a systematic progression. Innovation is more adventurous, more spontaneous, and more opportunistic. The triggers are many. Government incentives can be triggers, provided that they are formulated with full knowledge of the private sector environment, where innovation responds to a variety of independent stimuli. Most often, however, government incentives (including R&D funding) are not primary triggers; *they are additive*, providing the final margin of excitation to complete a process already begun.

Broadly speaking, technological innovation requires the *convergence* of six elements: (1) knowledge generated through R&D, (2) user need, (3) an advocate or champion, (4) availability of resources, (5) favorable risk factors, and (6) favorable timing. Government incentives can sometimes supply or compensate for missing elements. Where the need is high in national priorities, the incentive may be multipurpose, providing several elements, such as the resources needed as well as favorable risk factors.

It is true that technological innovation can be goal-oriented and can be managed. This has been demonstrated amply by both the private and public sectors, and sometimes by a combination or consortium of the two sectors. In the public sector, managed innovation typically involves large front-end risk, a dedicated primary customer (the government itself – as in Defense and Space Exploration), ample resources, and stipulated lead time. In the private sector, innovation is managed in response to competitive drives based on expectations of significant rewards from the marketplace. Successful major innovation generated by the private sector alone is relatively rare. More common is evolution based on incremental changes, involving more modest investments and risks.

Conventional wisdom holds that technological innovation is a response to recognized demand or need. However, “demand-pull” need not be the sole stimulant to innovation. “Technology-push,” though sometimes derided as “solutions looking for problems,” may be fully as influential. There is a good deal of evidence that corporations with a successful track record of innovation have developed organizational and operational practices that encourage “creative tension” between the push and the pull modes. This suggests that policies for federal funding of civilian R&D should be *part of a strategy* of investment pointed towards the identification and pursuit of opportunities for innovation. Technological change should be concerned not only with the change *per se*, but also with the *quality* of the change.

* Technological innovation is the process by which an idea or invention is transformed to play a significant role in the economy.

Apart from the (debatable) inducements to strengthening the national technology base provided by the IR&D allowances in government contracting policies, little concern has been shown for exploiting federally-funded R&D to enhance civilian technological innovation. Federal R&D is dominated largely, though not entirely, by the requirements process, which has its roots in the statutory missions of the funding agencies. An agency typically conducts or contracts for R&D to get solutions for which the agency is the single customer or "lead" agency. There is rarely any federal strategy aimed at propagation and application of research and development results in the industrial society. Indeed, there is some evidence that the rules of practice for industrial participation in mission-agency R&D create built-in barriers to commercialization of this technology, such as the non-exclusivity policy on patents.

Thus federal R&D funding obviously carries no fail-safe assurance that the business agent will pursue the innovation. In most cases, it is but one factor in the complex calculus of business behavior in risk-taking for innovation. The effect of federal R&D funding, per se, turns out positive to the extent that it escalates the firm's priority of R&D (as in Nuclear Power, for instance), or to the degree that it overcomes the problems of adverse risk and opportunity cost (as intended in Urban Mass Transportation R&D), or to the extent that it pre-organizes market interest and demand (as, for instance, through regulation, in Motor Vehicle Safety).

On the other hand, federal R&D funding, per se, is ineffective if its behavior is erratic and unreliable (as in Coal Research, for instance); if it carries the R&D too short of the transfer point, relying on momentum or poorly understood market forces to do the rest (as in Biological Pesticides and Edible Soy-Protein); and if it takes institutional factors for granted and misjudges them (as in all of our case studies to a greater or lesser extent).

ADL's recent work on "Barriers to Technological Innovation"* provided indicative information to the effect that where innovation goes slowly, it is largely because of market uncertainties, risk considerations, and anomalies in the decision-making behavior of the firm. To a degree, sentiment emerged from the business community as suggesting that the rate of innovation might be higher if government removed some of the constraints and uncertainties it imposes on innovation, than if it provided more R&D support — or, in other words — if more attention were given to the "pull" rather than the "push" mode.

*"Barriers to Innovation in Industry: Opportunities for Public Policy Changes," Arthur D. Little, Inc., Report to the National Science Foundation, September 1973, NTIS Reference Numbers PB229898/PB229899.

The point of these observations is that the ability of business to perform as the agent of technological change is dependent upon a very wide range of factors and influences which *interact* among each other: timing, perceptions of the market, the calculus of opportunity and risk, the objectives of the firm, expectations of returns, the structure of competition — and to some degree, the role of government wearing its several hats as policy-maker, R&D funder, and regulator (and purchaser, though this role is specifically excluded from consideration in this study).

We therefore conclude that federal R&D funding policies must be formulated as one possible component in this complex framework of interacting factors which trigger the process of innovation, and some of which are significantly influenced through government policies and actions other than R&D funding.

II. EFFICIENCY OF FEDERAL POLICIES TOWARD SUPPORT OF CIVILIAN R&D

In this chapter we discuss the implications of conclusions reached through our research in the six target sectors of our study, (reported fully in Volume 2: Case Studies). As was noted before, the objectives of federally-funded R&D in three sectors included aiding the commercialization of the R&D results (Nuclear Power, Urban Mass Transportation), or of existing technology (Motor Vehicle Safety). In the other three sectors (Coal, Food Processing/Soy-Protein, and Biological Pesticides), this was not an explicit objective.

However, the primary purpose of this study is to:

Increase the understanding of how federal R&D funding has in fact functioned as an agent of technological change in the private sector.

That means to say, we are concerned with "commercialization" of R&D results (and/or new use of existing technology), i.e., with "Technological Change in the Private Sector." We must therefore discuss Task 6 of this study, "Efficiency of Federal Policies Toward the Support of Civilian R&D," with the objective of commercialization in mind (regardless of whether commercialization was, or was not, an explicit objective for the federal funding of R&D in each of the sectors).

A. INTRODUCTION

In Chapter I, we noted that commercial innovation is most likely to succeed when *convergence* of a number of factors takes place (or if conditions for such convergence can be brought about by concerted public/private policies and actions):

1. *Technical Knowledge*, i.e., in this case the results of federally-funded R&D; and not only knowledge of hardware but also of related socio-ecological-behavioral factors.
2. *User Needs* — both for end-users of products, as well as for manufacturers of products, and, in the context of federally-funded R&D, preferably expressed as needs by a recognized "constituency" of the Executive or Legislative Branches, i.e., in this case:

	<i>End-User</i>	<i>Manufacturer</i>
Central Station Nuclear Power	Utilities	Reactor, fuels, etc.
Coal Extraction and Conversion	Utilities	Mining industry, conversion "industry"*
Motor Vehicle Safety	Individual	Automobiles
Urban Mass Transportation	Individual and City	Transport equipment
Soy-Protein	Individual	Food processor; Farmer
Biological Pesticides	Farmer; Public Agencies	Pesticide industry

*Put in quotation marks because such industry does not yet exist.

The term "user needs," in this context, encompasses both "user demand" and "public acceptance."

3. *Advocate or Champion*, i.e., one or more individuals and/or public or private institutions – in either case visibly and actively fully committed to ensuring that means exist or are created to carry the innovation through to commercialization.
4. *Resource Availability*, i.e., human, material, technical, and financial resources.
5. *Favorable "Risk Factors,"* i.e., economic, political, and institutional factors (e.g., corporate policies and industry dynamics in the private sector; or legislative, regulatory, fiscal, or other mandates, incentives, constraints in the public sector) which are – or can be through appropriate public policy measures – "orchestrated" to create the environment in which risk-taking in pursuit of technological change is an attractive opportunity for private-sector entrepreneurship.
6. *Timing*, i.e., action either or both in anticipation of or in reaction to existence of the foregoing five factors, so chosen as to take advantage of potential convergence occurring.

These six critical factors for convergence need not always be present in equal proportions. Special characteristics of industry sectors (their market dynamics, regulatory and financial environment, etc.) need to be taken into account in order to weight the importance of each of these factors, as the degree of convergence is assessed, in order to determine whether and where government intervention to supply "missing links" or "trigger mechanisms" for convergence are likely to be most effective.

It is evident from our research on the six target sectors chosen for this study that two factors, at least, are consistently of high priority for all the sectors (and likely to be for any other that might have been studied). They are "user needs" and favorable "risk factors." If these are missing in the convergence of critical factors, government action – through measures additional to R&D funding – may well be called for. This applies particularly to "Risk Factors," since many of them – as seen from industry's point-of-view – are the result of existing government policies and actions, or lack thereof.*

The other factors have differing degrees of importance in the convergence pattern. We have made professional judgments (based on our findings described in the detailed account of our case studies – see Volume 2) on the relative weighting to be given to each of these factors in each sector, and have rated them accordingly in the following indicative findings.

*See "Barriers to Innovation in Industry: Opportunities for Public Policy Changes," Arthur D. Little, Inc., Report to National Science Foundation, September 1973 (available through National Technical Information Service Reference Nos. PB229898, PB229899).

B. INDICATIVE FINDINGS

Postulating the convergence of these "critical factors" as a necessary condition for successful commercial innovation, we examined the conclusions drawn in the six target sectors of our study. Table 1 shows the results indicatively, and the following text discusses the implications of our findings.

It is worth stressing right at this point that knowledge (i.e., in this case, the results of R&D that was federally funded, but – for that matter – regardless of its funding origin) is a prerequisite for successful innovations, but not sufficient by itself to assure or even, necessarily, to stimulate successful innovation.

In Table 1, we have used an index of 0 to 5 for each of the factors critical for innovation. Zero denotes the weakest rating, 5 the strongest. These are admittedly no more than highly-informed, professional judgments and are thus only qualitative indicators rather than quantitative measures. The following comments will serve to illuminate the significance of these indicative ratings and their rationale.

Table 1 indicates that Nuclear Power and Motor Vehicle Safety show a high degree of convergence of the factors critical for innovation. In both cases, knowledge, user need, advocate/champion, and favorable risk factors rate high in contrast to the other sectors.

Urban Mass Transportation and Coal show a relatively low degree of convergence, primarily because of unfavorable risk factors (largely due to indecision or lack of adequate policy measures – additional to R&D funding – by the federal government), low resource availability, low user need, and poor timing.

Soy Protein and Biological Pesticides show almost no convergence because of absence of user need and advocate/champion, unfavorable risk factors, and poor timing.

In short, those federally-funded R&D programs – in our sample – that have shown most success in being "agents of technological change in the private sector" are those where:

- relatively close mutual understanding of public/private policies and action was achieved;
- public policy measures – additional to R&D funding – were introduced to create favorable risk factors;
- an advocate or champion existed in the public sector; and
- user need was stimulated, or mandated by regulation.

In the following sections, we discuss these issues in greater depth – albeit summarily – with respect to each of the target sectors. We refer the reader to Volume 2 for the detailed analysis and discussion of the circumstances and events in each of the target sectors that led us to the conclusions presented in this chapter.

TABLE 1

CONVERGENCE OF CRITICAL FACTORS FOR INNOVATION

	Nuclear Power	Coal	Motor Vehicle Safety	Urban Mass Transportation	Soy Protein	Biological Pesticides
Knowledge	4	2	4	3	2	3
End Users	4	2	1	1	1	0
User Need	3	1	5	1	1	0
Manufacturers and Suppliers						
Advocate/Champion	5	0	4	3	0	1
Resource Availability	4	3	5	2	3	3
Favorable Risk Factors	4	0	4	0	0	0
Timing	4	1	4	2	1	1
Total (out of 35)	28	9	27	12	8	8

No Convergence:	0-8	Total Score
Low Convergence:	9-17	
Medium Convergence:	18-26	
High Convergence:	26-35	

C. CASE-STUDY FINDINGS

1. Central Station Nuclear Power

Knowledge

- The objective of federally-funded R&D was to aid Atomic Energy Commission's statutory mandate to:
 - advance the commercial applications of nuclear power; and
 - promote private enterprise in this field.
- As reported in Volume 2, R&D was successful in providing the necessary technical knowledge, with some shortcomings in regard to reactor safety and fuel-cycle operations.
- Hence, our rating is 4 (out of 5).

User Need

- *End-users* (utilities) were highly motivated to acquire nuclear power (initially because of public versus private power issue; later, because of the favorable economics of "turn-key" offers by nuclear power plant manufacturers; most recently, because of high prices of alternate fuels).
- Our rating of 4 (out of 5) reflects uncertainty arising from safety problems and related issues of public acceptance.
- *Nuclear power plant manufacturers* were strongly motivated because of, initially, likely — and later, demonstrated — utility market opportunities. Potential suppliers of nuclear fuel cycle commodities and services were not so strongly motivated because of insufficient incentives, some deficiencies in technical knowledge and uncertain market factors due to the problems discussed above under "end-users."
- Our rating of 3 (out of 5) reflects these reservations.
- *Both users* (of R&D) were recognized as a strong constituency, both by the cognizant executive agency (Atomic Energy Commission) and Congress (Joint Congressional Committee on Atomic Energy).

Advocate/Champion

- Both the Executive Branch (the AEC) and Legislative Branch (the Joint Committee on Atomic Energy) acted as strong champions. Individuals in both organizations stood out as consistent advocates for nuclear power.
- Industry executives, both in utilities and reactor manufacturers, likewise acted as champions and moved their respective companies to sustain high risk-taking in pursuit of nuclear power.
- Hence our rating of 5 (out of 5).

Resource Availability

- Physical, human, technical resources were well-marshalled.
- Our rating of 4 (out of 5) reflects more recent financial strictures in the utility business and also some question as to long-term availability of uranium at reasonable prices (which may become less critical as and when the breeder reactor, now under intensive development, reaches the stage of commercial application).

Risk Factors

- These were made favorable, inasmuch as AEC and Congress provided a range of incentives and subsidies to the fledgling nuclear power industry. These included:
 - a. Uranium enrichment (to date).
 - b. Fuel reprocessing and waste storage on a firm, reasonable price basis (1957-1967).
 - c. Buy-back of plutonium at higher price than recycle value (1957-1967).
 - d. Waiver of interest charges on government-owned fuel used in demonstration plants (1955-1963).
 - e. Insurance indemnification (Price-Anderson Act of 1957).
- These additional public policy measures were all relatively effective. By far the most effective was the combination of incentives used in the Power Reactor Demonstration Program (i.e., R&D funding, plus items d. and e. above).

- Our rating of 4 (out of 5) reflects the fact that AEC's public information program did not adequately deal with safety aspects of central station nuclear power reactors, with resulting ambiguities which were challenged by public interest groups, leading to delays in the regulatory system; certain premature curtailment of R&D funding in light of reactor manufacturers' "turn-key" offers; and inadequate recognition of transition problems from the R&D Demonstration Plant stage to a self-sustaining commercial nuclear power industry (as discussed in detail in Volume 2).

Timing

- Though considered premature by some authorities in the utility business, hindsight (particularly in light of the energy crisis, predicted by knowledgeable authorities even in advance of the 1973 OPEC oil embargo) suggests that timing of convergence of critical factors was reasonably accurate. Nuclear (Fission) Power and Coal are indeed our major resources for energy-sufficiency in the remainder of this century.
- Hence our rating of 4 (out of 5).

2. Coal Extraction and Conversion

Knowledge

- The policy vacuum under which relatively low-level R&D funding was conducted in the Bureau of Mines and Office of Coal Research until recently has produced technical knowledge which was not assessed as to its commercial usefulness, even though specific programs were continued over many years.
- Research performers – even while they were private sector organizations – were not those who had potential interests and resources for commercializing the results of R&D.
- The problems of survival for coal producers and the problems of bringing a "new industry" into being for potential coal-converters (gasification and liquefaction) are dominated by "risk factors" (see below), in addition to new technology needed to make the industry (both extraction and conversion) realize its full potential.
- Redirection and greatly increased R&D funding for coal research, together with a mandate to evaluate R&D programs for potential commercialization, were only recently legislated by Congress and are now beginning to be implemented by the Energy Research and Development Administration (ERDA) as part of a new National Energy Policy.

- Our rating of 2 (out of 5) reflects the situation prior to these recent events.

User Need

- *End-users* (utilities) have considered coal as a "swing-fuel," depending on availability and price of oil, gas, and, more recently, nuclear power. The same applies even more (because of as yet non-applied technology of coal conversion) for synthetic gas or oil produced from coal.
- These uncertainties in markets for coal and its derivatives is the reason for our rating of 2 (out of 5).

Advocate/Champion

- There was no advocate/champion (individual or institutional) in either the public or private sector to push for major coal-related technological innovation.
- Hence our rating of 0 (out of 5).
- Recent events (establishment of ERDA, Congressional mandates, Executive initiatives on strip mining legislation) could provide opportunity for new leadership, if not outright advocacy.

Resource Availability

- Although potentially very plentiful, coal-extraction productivity and coal-conversion potential are restrained by unfavorable risk factors (see below), and resource availability is therefore limited and inhibited in its growth.
- Hence our rating of 3 (out of 5).

Risk Factors

- These were unfavorable and not ameliorated by public policy measures. The principal restraints include: market uncertainties, transportation and manpower deficiencies, equipment shortages, and lack of capital availability to embark on capital-intensive technical innovation, both in coal extraction and conversion.
- Hence our rating of 0 (out of 5).

Timing

- Until the energy crisis became dramatically visible with OPEC embargoes and oil-price rises, timing for convergence of critical factors was unfavorable. Utilities

had alternative and economically more attractive sources of fuel than coal; coal conversion was not price-competitive.

- Current development of a national energy policy shows the beginning of a more timely convergence, though we doubt that this will occur unless an unambiguous national commitment is made for coal as a fully recognized, integral part of such a policy for a period of several decades.
- Hence our rating of 1 (out of 5) for the past period under review in this project.

3. Motor Vehicle Safety

Knowledge

- The objective of federally-funded R&D in this field is markedly different from those in the other target sectors. By Congressional mandate, the National Highway Traffic Safety Administration is charged with rule-making on, and enforcement of, *mandatory performance standards for automobile components*, designed to decrease the risk of injury or other loss in accidents. The R&D funded by the agency is designed to *justify* the standards which embody *known* technology. It is not designed to deliberately generate new technical knowledge.
- Our rating of 4 (out of 5) reflects the assertion that the agency is slow to incorporate all relevant R&D results in its standard-setting, and also that its philosophy of "forcing" application of existing technology may foreclose private initiative to seek (and fund) new technologies for the same overall objective of reducing risk or injury or other loss.

User Need

- The *end-user* (automobile driver) has demonstrated through his behavior that he is not "sold" on the need for safety devices (e.g., seat belts or other restraints) to reduce his risk of injury or death. "It's the other guy who gets hurt; I am a good driver."
- Hence our rating of 1 (out of 5).
- The *manufacturer* (Detroit), though frequently in an adversary position on the efficacy of the mandated standard, is being forced by federal regulation to adopt it.
- Hence his need, though not self-generated, is rated at 5 (out of 5).

Advocate/Champion

- Strong individual champions in the Executive Branch, Congress, and public interest groups were active in focusing public attention on the issue of Motor Vehicle Safety.
- The resultant Motor Vehicle Safety Act of 1966 mandated what became the National Highway Traffic Safety Administration (NHTSA), which itself now acts as advocate/champion, albeit in frequent disagreement with the manufacturers, whose championship for safety is still lacking (because this "feature does not sell").
- Hence our rating of 4 (out of 5).

Resource Availability

- Human, material, technical, and financial resources exist to make enforcement of mandated standards politically and practicably acceptable.
- Hence our rating of 4 (out of 5).

Risk Factors

- In spite of little end-user demand, and extra costs of safety features mandated, the simple fact that such features are a regulatory requirement is overriding and makes the risk factors favorable for using technology to enhance safety.
- Our rating of 4 (out of 5) reflects the shortcomings cited under "knowledge" above.

Timing

- The rapidly rising toll of automobile accidents, coinciding with public interest advocate Nader's dramatic entry on the scene, and federal concern, made timing for convergence of critical factors favorable.
- Our rating of 4 (out of 5) reflects the lack of "orchestration" between public policy mandates and private industry interests.

4. Urban Mass Transportation

Knowledge

- The objectives of federally-funded R&D fluctuated markedly from software research to hardware research and back again, reflecting strong views of Urban Mass Transportation Administration (UMTA) (and predecessor organizations) administrators, its R&D directors, and U.S. Department of Transportation (DOT) Secretaries' political aims.
- Neither set of objectives was pursued far enough, or long enough, or with enough commitment and technical/economic/social understanding of the users' needs, to show definitive results. The outcome of several major RD&D projects still being pursued is uncertain.
- Our rating of 3 (out of 5) reflects this see-saw mode of policy and objective setting and resultant deficiencies in conduct of federally-funded R&D.

User Need

- The *end-user* (individual riders of urban mass transportation systems) is not a "constituency" with voice or clout in federal decision-making. Except for the poor, elderly, and handicapped, the presumption is that we must be "forced" into mass transportation, but no such public policy measures are evident or likely to be politically acceptable.
- Cities (considered as "users" of urban mass transportation) are financially unable to bear operating costs which persistently show deficits, and they are not interested in being "guinea pigs" for new mass transportation systems untried in revenue-producing service.
- Hence our rating of 1 (out of 5).
- The *manufacturer* of mass transportation equipment sees a speculative and fragmented at best, or more generally, no clearly discernible market for his potential technological innovations. He is perplexed by dichotomies in UMTA's R&D vs. Capital Grant Policies, and cannot afford to go further in committing resources without clarification of federal policies.
- Hence our rating of 1 (out of 5).

Advocate/Champion

- UMTA is intended to function as such, but its history of rapid turnabouts in policy has left both users and manufacturers disenchanted, as well as Congress (reflected in Congressional cuts of UMTA's R&D budget).
- There is no credible or powerful champion in the private sector, other than individuals without necessary clout.
- Our rating of 3 (out of 5) may indeed be generous.

Resource Availability

- Because of situations described above, technical resources are not sufficiently available.
- Financial resources (even with diversion of some Highway Trust Fund money to mass transportation at discretion of states) are inadequate to build and operate sufficiently well-performing city-wide transportation systems to attract ridership.
- Hence our rating of 2 (out of 5).

Risk Factors

- The foregoing factors illustrate a spectrum of unfavorable risk factors which is not likely to be rectified other than through concerted federal/state/local government policies and actions.
- None are yet visible or credible.
- Hence our rating of 0 (out of 5).

Timing

- Should be favorable for convergence of critical factors, considering the highly adverse effects that poor transportation has on the quality of urban life.
- National leadership is still needed to bring about this convergence.
- Hence our rating of 2 (out of 5).

5. Soy-Protein

Knowledge

- The principal agency for R&D funding is the U.S. Department of Agriculture, and the Agricultural Research Service in particular. Its principal objective is to improve agriculture productivity and its funding policies are heavily affected by vested interests in the agribusiness sector and their influence in Congress.
- Hence, Soy-Protein has received relatively little attention – in spite of long-standing recommendations that sources supplementary to animal protein need to be developed for the social and economic well-being of the country: one of the Agricultural Research Service “constituencies,” the livestock farmer, may be adversely affected by an alternative source of protein.
- Hence our rating of 2 (out of 5).

User Need

- The *end-user* (consumer) has not yet shown a direct preference for this protein source per se.
- Hence our rating of 1 (out of 5).
- The *manufacturer* has other major end-markets for soy oil and soy meal (the current principal end-products of soybean processing), and is disinclined to jeopardize these markets (particularly soy meal – his biggest – for animal feed) by pushing for human soy-protein consumption directly without “going through the tummy of the animal.”
- Hence our rating of 1 (out of 5).

Advocate/Champion

- There is no strong advocate/champion for Soy-Protein for human nutrition. Individual, and respected, authorities have urged further development, but have not yet prevailed against political or economic power or vested interests offering still viable alternatives.
- Hence our rating of 0 (out of 5).

Resource Availability

- Other than absence of user needs and relative paucity of technical knowledge, other resources are available.
- Hence our rating of 3 (out of 5).

Risk Factors

- Lack of user need, absence of effective champion/advocate, and decentralized initiatives in policy-making, make for highly unfavorable risk factors, none of which have been the subject of deliberate and sustained federal or industry attention. A few exceptions to this were noted (e.g., federal school lunch program creating market for soy-protein).
- Our rating is 0 (out of 5).

Timing

- Timing for convergence of critical factors has not been propitious to date, largely because of availability of economically and technically viable alternatives to soy-protein.
- However, it may not be long before timing becomes more propitious, e.g., when meat, poultry, and dairy product prices in the United States motivate the consumer to look for other protein sources (i.e., soy-protein).
- Our rating is 1 (out of 5) to reflect this trend.

6. Biological Pesticides

Knowledge

- The principal federal agency for R&D funding is the U.S. Department of Agriculture (USDA) and, within it, the Agricultural Research Service, the Cooperative State Research Service, and the administration of Hatch Act Funds.
- The principal objective of federal R&D funding has been to enhance knowledge of biological controls through basic research, as contrasted to knowledge derived from application research. The latter has received comparatively less attention because the largest group of users (farmers), who are USDA's principal "constituency," had other, and more effective, methods available for pest control.
- Hence our rating of 3 (out of 5).

User Need

- The principal end-user (farmer) has still available to him chemical pesticides that are effective, economic, relatively simple to use, and still sanctioned for use environmentally. Hence, he has little need for biological controls which may be environmentally even "safer," but which compare unfavorably on all other counts.

Another, and smaller, group of end-users are federal and state agencies (such as the Forest Service, Soil Conservation Service, mosquito control districts, right-of-way users), who are more inclined (than farmers) to use biological controls because of their effectiveness in wide-area applications (a need seldom experienced by farmers).

- Our rating is 0 (out of 5).
- Most *manufacturers* of chemical pesticides are not set up to handle production and distribution of biological pesticides and, more importantly, see only low-volume markets developing. They are therefore not inclined to incur high risks and costs (testing, Environmental Protection Agency registration, etc.), in introducing biological control products.
- Hence our rating of 0 (out of 5).

Advocate/Champion

- Though in the past there were some strong advocates, their power diminished as superior cost-benefit considerations of alternative chemical methods, then being developed, supervened.
- Individual, and respected, scientists continue to urge further biological control developments, and their voice may regain more power as the environmental movement continues to oppose the use of chemical methods.
- Hence our rating of 1 (out of 5) to reflect this trend.

Resource Availability

- Absence of user needs.
- Availability of scientific resources.
- Potential availability of industrial capability if markets and profitability could be foreseen.

- Hence our rating of 3 (out of 5).

Risk Factors

- On the federal side, multi-agency uncoordinated R&D programs, not stimulated by perceived user-need.
- On the industrial side, uncertainty about effectiveness of biological control methods and environmental and health considerations, lack of market and return on investment.
- Hence our rating of 0 (out of 5).

Timing

- Timing of convergence of critical factors has not been propitious to date, largely because of availability of economically and technically effective alternatives to biological pesticides.
- However, it may not be long before timing becomes more propitious because ecological imperatives may make use of chemical pesticides still less acceptable, and focus attention on biological methods, or, at the very least, on integrated (i.e., chemical *and* biological) pest control methods.
- Hence our rating of 1 (out of 5) to reflect this trend.

D. ADDITIONAL CONSIDERATIONS

One of the convergence factors discussed in Section II B, namely "Favorable 'Risk Factors'," encompasses a wide range of economic, political, and institutional issues. Among those governed by public sector policies are regulatory and fiscal incentives and constraints. Some of these have a direct relationship to federal funding of R&D, and are relatively uniform across all the sectors of industry. One such is patent policy, particularly as it applies to proprietary rights emanating from federally-funded R&D.

In our study for the National Science Foundation on "Barriers to Innovation in Industry,"* we researched this issue and obtained valuable insights into industry and government perceptions of it. We are therefore quoting our summary findings on this subject here:

- The perceived value of patent protection is being eroded as some 60% to 80% of contested patents are found invalid by the courts. Court decisions are

**Ibid.*

non-uniform, and criteria used in judging patent validity vary widely from jurisdiction to jurisdiction.

- Government-held patents are being licensed to industry on a non-exclusive basis. This creates uncertainty about competitors' posture and reduces interest in commercializing such inventions.
- There is ambiguity on exclusive versus non-exclusive licensing – by fields of use – of patents held by an inventor or corporation. Exclusive licensing would encourage utilization. Differences in policy position between the Department of Justice and the Department of Commerce highlight this issue.
- Trivial and invalid patents clutter up the patent field and constitute “nuisance” obstacles to “serious” innovations. A “petty patent” system with lesser degrees of protection, as practiced in some other industrialized countries, could clear the air.

Specifically, with regard to patents resulting from federally-funded R&D, we noted the following:

“Government Ownership of Patents”

Perceptions Held by Private Industry

Government R&D contracts should sometimes provide for ownership by the private firm of patents developed under the contract, with provision for compulsory reasonable licensing to competitors. This would give added incentive to the contracting firm, because it would gain a unique position to exploit the patent in the commercial market. As an alternative, the government should be required to demonstrate a ‘need to own’ for such technology where it insists on retaining ownership.

Perceptions Held by Public Sector

Government versus private ownership of patents developed under government contracts has recently been studied in depth by the Commission on Government Procurement. In its report of December 1972, the Commission describes extensively both the built-in and administrative weaknesses of the August 23, 1971 Presidential Policy Statement on Patents (which strengthened the 1963 Statement of Government Patent Policy issued by a previous Administration). While the Commission staff on patents recommended that new legislation be enacted to allow government contractors to obtain exclusive commercial rights to inventions (subject to strong ‘march-in’ rights administered by a government board), the Commission included this idea as ‘an alternative approach,’ but recommended

that: 'major departure in the patent rights area should be deferred until the revised policy has been evaluated. . . in light of actual agency experience.'

Government "Reachback" in Contract R&D

Perceptions Held by Private Industry

In certain government R&D contracts, free licensing of previously private work know-how and patents is required as a 'reachback' condition of the contract. Respect for previous industrial property rights or fair compensation would eliminate or modify the reachback of such provisions and eliminate this impediment to R&D work by industry under contract to the government.

Perceptions Held by Public Sector

Federal officials knowledgeable about background rights feel that the facts have been overstated. They point out that the Department of Defense has no reach-back provisions as a condition of R&D contracts, while the Department of the Interior does. AEC and NSF also have reachback provisions, but they are essentially dependent on the agency's need for the private contractor and the case for know-how and patent position presented by the contractor. The Commission on Government Procurement also studied this complex issue, but sidestepped it entirely in its December 1972 Report. The issue is, however, being actively reviewed by the Ad Hoc Committee on Background Rights of the Federal Council for Science and Technology."

E. CONCLUSIONS

The principal conclusions on Efficiency of Federal Policies Toward the Support of Civilian R&D that we draw from our research are presented in Chapter I of this report. More specifically, we also conclude that:

1. Federal R&D funding, absent a mix of supportive incentives and rewards, has not been efficient in achieving technological change in the private sector to any significant extent.
2. Federal policies for the support of civilian R&D are effective where procurement has leverage on adoption and utilization of the R&D products (as in Central Station Nuclear Power and Motor Vehicle Safety).
3. Federal funding for R&D is insufficient to offset regulatory constraints on civilian industrial innovation (as in biological pesticides — testing and registration; and as for all industry sectors in regard to patent policy).

4. Federal policies towards civilian R&D are often transitory and non-inclusive, and their benefits are elusive and of little significance for social and economic well being (as in Urban Mass Transportation R&D).
5. The mix of federal policies towards civilian R&D is unbalanced and incomplete because it does not take into account user needs and industry dynamics (as in Edible Soy-Protein R&D; and Coal R&D).

III. SIGNIFICANT CHARACTERISTICS OF SELECTED CASE STUDIES

In this chapter we summarize the findings of our field research, undertaken in the six target sectors and described fully in Volume 2 of this report. These summaries are arranged under the six Task headings posed by ETIP for this project, so as to facilitate cross-comparison between the case examples.

Table 2 presents this information in summary form. In subsequent sections of this chapter we elaborate on the most significant characteristics – albeit still in a highly summarized format. For the purpose of this Summary Report, we intend no more than to convey the essential flavor of the role of federally-funded R&D in each of the target sectors.

With reference to Table 2, we draw attention to the following cross-comparisons between the target sectors, by Task.

Task 1 – Origin of Civilian R&D Policies

The spectrum of policy origins ranges from relatively low-level technical offices in mission agencies (e.g., USDA/ARS for Edible Soy-Protein and Biological Pesticides, DOI/BOM and OCR for Coal) to high-level Executive and Congressional mandates or support (e.g., White House/Joint Committee on Atomic Energy for Central Station Nuclear Power; Department of Transportation/Office of the Secretary-UMTA Administrator for Urban Mass Transportation). Where high-level policy support was steadfast over the years, the climate for effective R&D funding was improved. Where policy was made at lower levels without “national commitment” (particularly in the absence of understanding user needs and industry dynamics) the policy directions and priorities of R&D funding suffered and the work was largely undertaken for its own “scientific” value, rather than for its “utilization” potential.

Importantly, the origins of R&D policies generally do not reflect any inputs from – let alone thorough understanding of – industrial interests who would be expected to take the risks in transforming technical knowledge derived from the federal R&D into commercially viable products and processes. The spectrum on this issue ranges from essentially no inputs at all (as in Coal R&D) to some long-range “scenario” development (as in Nuclear Power). But even where the latter was performed, postulating the kind of commercial enterprise that may exist ten to fifteen years hence (making various technical, economic, and – even – social assumptions), the picture was incomplete in that it did not identify the kind of “self-interests” possessed by the various institutions performing the scenario at that time. Without at least speculating on those dynamics, and contrasting them with the current self-interests of these “actors,” it is unlikely that routes for “how to get from here to there” can be mapped and sound public policies be developed to overcome barriers. Considering moreover that such an exercise in “strategic techno-institutional forecasting” should be conducted jointly by government and industry to achieve credibility and commitment to

TABLE 2

SUMMARY OF SIGNIFICANT CHARACTERISTICS OF SELECTED CASE STUDIES

	TASK 1	TASK 2	TASK 3	TASK 4	TASK 5
Case Study	Origin of R&D Policies	Allocation Policies for R&D Funding	Objectives of R&D Funding	Alternatives to R&D Funding (Additional Incentives)	Efficiency of R&D Funding
Central Station Nuclear Power	<ul style="list-style-type: none"> • Congressional and Presidential Mandates • Increasing Government-Industry Interaction 	<ul style="list-style-type: none"> • Open-Ended Multi-Year Funding for Major Programs • Broad Range of Basic and Applied R&D and Demonstration Projects 	<ul style="list-style-type: none"> • Advance Central Station Nuclear Power • Promote Private Enterprise • Shorten Lead-Time for Innovation 	<ul style="list-style-type: none"> • Fuel-Cycle Subsidies • Insurance Indemnity • Subsidies for Capital Costs on Demonstration Project 	<ul style="list-style-type: none"> • Additional Incentives made Federal R&D Funding Effective • Problems of Transition to Commercialization with Public Acceptance Not Sufficiently Understood
Coal Extraction and Conversion	<ul style="list-style-type: none"> • Policy Vacuum • Mission-Oriented as perceived by DOI Research Staff • No Industry Input 	<ul style="list-style-type: none"> • Incremental Growth to Maintain Baseline Effort-Budget Sensitive • Influenced by Unsolicited Proposals from Other than Industry • Non-Evaluation of R&D Programs 	<ul style="list-style-type: none"> • Help Coal Industry from "Going Under" • Meet Balanced Congressional Mandates for Coal Conversion Potential 	<ul style="list-style-type: none"> • Not Considered • Need for Market and Price Stabilization; Cost/Effective Transportation; Capital Availability; Manpower 	<ul style="list-style-type: none"> • Absent a National Policy on Coal Utilization and Related Incentives, Federally-Funded R&D Ineffective
Motor Vehicle Safety	<ul style="list-style-type: none"> • Individual Champions Sparking • Congressional Mandate • Little Industry Input 	<ul style="list-style-type: none"> • To Support Enforceable Performance Standards for Vehicle Components, Using Existing Technology 	<ul style="list-style-type: none"> • Reduction of Losses Due to Vehicle Deficiencies 	<ul style="list-style-type: none"> • Not Considered • Mandatory Performance Standards are Effective "Pull" for Existing Technology 	<ul style="list-style-type: none"> • Forcing Existing Technology into Use May Foreclose New Approaches • Difficult to Measure Efficiency Because of Multiple Accident Causes; and Brief History of Performance Standards
Urban Mass Transportation	<ul style="list-style-type: none"> • Fluctuations Reflecting Proclivities of Administrators • Cities and Users Uninfluential • Industry Input Ineffective 	<ul style="list-style-type: none"> • Reduce Cost • Improve Attractiveness of Mass Transportation • Promote Efficient Land Use and Higher Quality of City Life 	<ul style="list-style-type: none"> • Improve Quality of Transit Service • Demonstrate Life Cycle Costs • Develop Prototypes of State-of-the-Art 	<ul style="list-style-type: none"> • Private Industry Unwilling to Make Large Investments • Cities Unable to Fund New Systems • UMTA Capital Grants Only Alternative, but Inadequately Linked to RD&D Program 	<ul style="list-style-type: none"> • Many Projects Still Incomplete and Not Susceptible to Evaluation • Efficiency of R&D Funding Impaired by Policy Fluctuations; Political Pressures; Failure to Perceive User Needs; Lack of National Transportation Policy
Edible Soy-Protein	<ul style="list-style-type: none"> • USDA's ARS Plus: • Congressional Pressures To Support Farmer and Existing Agribusiness • Soy-Protein as Alternate to Animal Protein: Low Priority 	<ul style="list-style-type: none"> • Increase Soybean Yield • Protect Established Markets for Soybean Products • Develop Edible Soy-Protein Though Competing with Existing Alternatives 	<ul style="list-style-type: none"> • To Develop Basic Knowledge of Soy-Protein Properties • While Major Objectives Focused on Soybean Yield and Existing Markets for Utilization 	<ul style="list-style-type: none"> • Not Considered Aggressively • School Lunch Program Provided Stimulus for Some Commercialization 	<ul style="list-style-type: none"> • Lack of Federal Commitment to Develop Edible Soy-Protein Minimal in spite of Anticipated Needs • Low Priority, Basic Research Ineffective as Base for Commercial Utilization
Biological Pesticides	<ul style="list-style-type: none"> • USDA's ARS, Forest Service; HEW: EPA • No Interagency Coordination 	<ul style="list-style-type: none"> • Decentralized Program Definition • No Industry Participation in R&D • Little Congressional and Executive Influence 	<ul style="list-style-type: none"> • Increase Basic Knowledge • Develop and Test Biological Techniques • Reduce Dependence on Traditional Pesticides 	<ul style="list-style-type: none"> • Interagency Coordination Needed • Ease Regulatory Constraints • Educate Farmer • Aggregate Public-Sector Market to "Pump-Prime" 	<ul style="list-style-type: none"> • Ineffective to Date to Promote Widespread Use • Availability of Still Approved Chemical Methods Preferred by Mfr. and User • Integrated Pest Management Seen as New Approach

action, one is struck with the difficulty of the task. Yet, without attempting it, the ship lacks essential navigational aids and is as likely to run aground as make harbor.

Task 2 – Policies for Allocating Civilian R&D Funds

Generalized criteria in government-wide use do not exist for the allocations of federal R&D funds. The range of allocation policies for R&D funding stretches from high-level support for multi-year, open-ended funding of a broad range of alternative technical approaches (as in Nuclear Power) through incremental R&D budget growth to maintain baseline technical efforts (as in Coal) to science-per-se-motivated policies of filling in gaps in fundamental knowledge (as in Edible Soy-Protein). Criteria for rationing R&D support are less stringent for mandated civilian innovation (i.e., Presidential and Congressional priorities) than for other civilian R&D which competes with agency program claims.

Special circumstances, such as political pressures, internal agency inconsistencies, and – once again – lack of understanding of the industry calculus of risk and pay-off, lead to policy fluctuations (as in Mass Transportation R&D) that reflect unwarranted optimism at one time, and overly cautious behavior at others. The performers of R&D, the industry that should use the R&D results, and the end customers are left bewildered and disenchanted, and R&D can only become relatively ineffective under such circumstances.

Task 3 – Objectives of Civilian R&D Funding

The objectives for federally-funded R&D are the obverse side of the coin discussed under Task 2. The same considerations apply, with the additional comment worth making that all too few R&D programs were subjected to rigorous evaluation of progress to determine whether they would likely achieve the desired objective. In Coal Research, for instance, programs continued for many years (say in coal gasification) without such examination, let alone constructively critical inputs from those sectors of industry that one would have wanted to become the industrial entrepreneurs in commercializing the R&D. The same can be said, to varying degrees, of Urban Mass Transportation, Edible Soybean, and Biological Pesticides.

On the face of it, some civilian R&D funding seeks to amplify the range and mix of choices open to the user market (as in Biological Pesticides, and Urban Mass Transportation). Some is funded to shorten the lead time for producing commercially applicable new products or processes (as in Nuclear Power). Some finances the incremental social cost of innovations which benefit the general public interest while burdening the industry (as in Urban Mass Transportation and, to some extent, in Motor Vehicle Safety). But, all that said, these objectives imply an understanding of user needs and industry dynamics all too often lacking in practice.

Task 4 – Alternatives to Civilian R&D Funding

Alternative – or more likely “additional” – public policy measures to stimulate utilization of R&D (funded from whatever source, public or private) were generally not considered explicitly. A prevalent presumption was held that the forces of the private marketplace would “pull” as soon as a feasible technology was “pushed” far enough along with federal funds. The “non-technical” barriers to commercialization were all too often overlooked, particularly when potential remedies (incentives) were clearly the province of some other agency (say, Treasury Department for fiscal ones). For institutional reasons, R&D funding is rarely traded off against alternative (or additional) policy strategies (e.g., deregulation, rapid amortization, investment credit) for stimulating innovations.

One striking exception is the Motor Vehicle Safety example. Here, an “additional” policy was in fact the dominant one, i.e., the mandatory requirements for, say, seat belts, forcing technology into commercial use regardless of whether manufacturers or users, individually, were convinced of the need. The public weal, as perceived by Congress, directed the course of events and market “pull” was legislated into existence.

One class of “alternatives” is receiving increased attention, i.e., aggregation of public sector markets. This can involve federal cost-sharing in producing advanced technology for federal, state, and local government markets (as intended in Urban Mass Transportation Capital Grants). It is too early to judge whether such incentive can motivate the industry to deliver “public” technological innovation in order to achieve early market position for private customers.

Task 5 – Relative Efficiency of Civilian R&D Funding

On the relative efficiency of R&D funding, our observations and analyses indicate that absent some high-level commitment – Executive and/or Congressional – and appropriate additional incentive measures, federal funding of civilian R&D is – alone – relatively inefficient in stimulating technological change in the private sector. To be sure, in some of our case studies certain major programs have not yet matured to the point where this can be said with complete certainty. But enough indications are discernible to throw considerable doubt on successful outcomes when R&D funding is the sole stimulant. Recent events suggest that this situation is being recognized and that beginnings are being made to correct it. For instance, the Energy Research and Development Agency is taking steps to consciously and deliberately address the potential for, and problems that may be encountered in, commercialization of its R&D. One would hope that such efforts will be seen not only as one-time planning tools, but rather as on-going activities of equal importance to the undertaking of the technical work itself. Technical and institutional change must go hand in hand, lest innovation be still-born.

More specifically, federal R&D funding is relatively more efficient than other strategies when barriers to market enterprise are so formidable as to preempt adequate or timely industry initiatives (as in Urban Mass Transportation, were it not for Department of Transportation/Urban Mass Transportation Administration (DOT/UMTA) Capital Grants practices that conflict at times with the R&D objectives).

R&D funding will be more efficient when the scale of the required effort does not match industry R&D structure or financial capacity (as in the early days of nuclear power).

Other alternatives are superior where the public interest factor is not congruent with market factors (as in Motor Vehicle Safety).

Other alternatives are preferable if the needed technology is already on the shelf or in an advanced state of readiness for development and what is needed is a trigger to induce convergence with a user market (as in Motor Vehicle Safety).

A. CENTRAL STATION NUCLEAR POWER

Task 1 – Origin of R&D Policies

- Congressional and Executive Initiatives

1946 Act: Transition to civilian control

1954 Act: Declassification of reactor technology and provisions for private ownership of facilities

1957 Act: Price-Anderson insurance indemnification

1964 Act: Private ownership of fuel

- Strong Joint Committee on Atomic Energy (JCAE) Support throughout History of Program

- Presidential Endorsements:

e.g., Eisenhower's "Atoms for Peace" Program

Kennedy's 1962 AEC Report

Nixon's Breeder Program

Characteristics

- User (utility) interest low until mid-'50's. Sparked by public power specter.

- Manufacturers (General Electric, Westinghouse, Babcock & Wilcox, etc.) interest low until mid'-50's, i.e., until prospective utility market opened and commitments to defense work levelled off.
- Characteristics of "top down" policy formation.
- Massive R&D dollar expenditures.
- Primary motivation in formative years was desire to exploit the power of the atom for purposes other than nuclear weaponry.

Task 2 – Explicit and Implicit Policies to Allocate Funds for Civilian R&D

Explicit

- Funding to advance state of technology including broad range of basic and applied research by universities, research institutions, national labs, and industry. (Open-ended, multi-year funding for major programs.)
- Joint Atomic Energy Commission (AEC) Electric Utility development programs: demonstration scale, designed to overcome user inertia.
- Avoid placing national labs in competition with private industry.
- Avoid placing any one firm in dominant technical position.
- Expect private sector to pick up R&D at reasonable stage of commercial maturity.
- Declassification, information-dissemination, and patent policies designed to make R&D results promptly and generally available (patent provisions probably handicapped commercialization).
- Stress high qualifications of key researchers.

Implicit

- "Conventional" plant components would be developed and tested by industry alone, in response to performance requirements, without federal R&D assistance.
- Transition from R&D (and demonstration) stage to commercial phase would be adequately governed and conducted by private market forces.

- Utility-manufacturers relationships well-defined and solid; hence, not necessary to make special provisions for coupling with R&D performer/manufacturers.
- Program definition subject to political pressure and compromises because of public vs. private power issue.
- Fuel cycle problems would not require nearly as much attention as reactor problem.
- Safety aspects would be solved in timely fashion, since safety records of military, research, and demonstration reactors were very good.
- Special safety R&D to support regulatory program would not be of primary importance.

Task 3 – Explicit or Implicit Objectives of Federal Civilian R&D Funding

Explicit

- Meet Congressionally-mandated requirements.
- Meet Presidential commitments.
- Advance the application of a central-station nuclear power.
- Promote private enterprise in this field.

Implicit

- Shorten lead-time for technological innovation.
- “Hot pursuit” of a technological opportunity related to a national (and international) need or priority.
- Maintain technological superiority in all aspects of nuclear technology.

Task 4 – Alternatives to Civilian R&D Funding

R&D was the chief instrument in achieving Nuclear Power objectives, but explicit additional incentives were provided to speed commercialization, e.g.:

- Subsidies in fuel cycle
 - guarantees of fuel prices
 - low-cost enrichment of uranium in government-owned facilities
 - storage of waste products
 - limited subsidies to uranium supply industry

- Insurance indemnity
- Subsidies for capital costs and certain engineering costs of Demonstration Reactors (Rounds 1, 2, and 3)
- Public information programs
- Regulatory incentives (waiver of anti-trust restrictions on early plants)

However, insufficient and/or non-timely attention was given to:

- Safety R&D and related "Public Acceptance" issues.
- Transition problems from small-scale demonstration plants to large commercial ones (with insufficient operational experience: scale-up too quick).
- Capital and/or tax subsidies and/or risk guarantees to utilities and manufacturers to avoid having to achieve scale-up cost savings (but politically probably impractical).

Task 5 – Relative Efficiency of Federal R&D Funding

Nuclear power would not have become an available energy option without the massive federal R&D support in combination with the additional public policy incentives outlined in Task 4. The type of additional incentives, their magnitude, and their timing were crucial stimulants for reactor manufacturers and electric utilities to develop technology that has high public interest motivation and calls for internalizing the objectives within industry practices. The major criticism of these additional incentives was that they were too modest in scope and duration.

Even so, there was still insufficient understanding in government of the industry dynamics (both manufacturers' and utilities') to foresee the problems of too rapid transition from the research, development, and demonstration phase (largely funded by government) to privately-funded, full-scale commercial operation. The manufacturers' decision to offer guaranteed, turnkey performance of greatly scaled-up plants proved to be premature. It cost them dearly in monetary terms; it misled utilities into massive orders at a time when operational experience was still insufficient to assure technical, economic and schedule parameters for the plants being offered; it exaggerated a growing public acceptance problem; and it led the AEC to curtail federal funding of additional R&D on the assumption that private industry would fully carry on that work. This proved erroneous, particularly with regard to R&D on safety-related issues, which now loom as one of the most critical issues retarding the rapid growth of nuclear power which is required to meet national energy needs.

Therefore, experience in the nuclear power field suggests that federal R&D funding *in combination with* additional public policy measures is effective, provided that both government and industry fully understand *all* implications of the technological and commercial goals to be achieved.

B. COAL EXTRACTION AND CONVERSION

Task 1 – Origin of R&D Policies

Extraction

- Bureau of Mines/U.S. Department of the Interior
 - Research stations initiative
 - Mission-oriented, baseline policies
 - low-level funding/incremental growth
- No Congressional initiatives, except for MESA's Safety Research (leading to Mining Enforcement and Safety Administration/Bureau of Mines competition for R&D).
- Characteristics of "bottom up" policy formation.
- No industry input.

Conversion

- Low-level funding, initiated by Office of Coal Research, built "close to the ground."
- Some external input, but not from those who would be potential owners/operators of conversion plants.
- Little credibility in Executive and Congress because no apparent technical/economic feasibility, nor national need.

Both

- Energy crisis (1974) belatedly triggered macro-decision to step up program: Executive (White House) initiatives; Energy Research and Development Administration; and greatly increased R&D funding in both extraction and conversion.

Task 2 – Explicit and Implicit Policies to Allocate Civilian R&D Funds

Extraction

Explicit

- Incremental budget growth to maintain baseline effort.

Implicit

- No “umbrella” guidelines, policy vacuum.
- Presumption that market demand would stimulate commercialization.

Characteristics

- Budget-sensitive funding.
- Funding to advance state of technology.
- Funding to compensate for gaps in technical know-how.
- Funding to buy time for process and policy decisions.

Conversion

Explicit

- Static budget.
- Policy vacuum, because lack of technical/economic credibility and no apparent need.

Implicit

- Industry interest would quicken as demonstrations showed promise.
- Resources (coal, water, and manpower) will be available.

Characteristics

- Same as for “extraction.”

Task 3 – Explicit and Implicit Objectives of Civilian R&D Funding

Extraction

Explicit

- Help in keeping coal industry from “going under,” i.e., accomplish a social goal.

Implicit

- Pump-priming of a neglected but needed field of R&D.

Conversion

Explicit

- Meet Congressionally-mandated requirements.
- Pump-priming of a neglected but needed field of R&D to increase potential range of options for possible commercialization.

Task 4 – Alternatives to Civilian R&D Funding

Extraction

R&D alone insufficient to achieve objective. Additional incentives needed include:

- Market and price stabilization for long-term utility contracts.
- Adequate and cost-effective transportation.
- Capital availability for opening new mines and purchase of mining equipment.

Conversion

R&D not yet sufficiently far advanced to judge if it will meet objective by itself. Likelihood that additional measures needed to assure availability of resources, i.e., large quantities of coal, water, capital, and manpower.

Task 5 – Relative Efficiency of Civilian R&D Funding

Federal funding of R&D in coal extraction – and even more so in coal conversion – has, until last year, been conducted in a policy vacuum. The relatively low level of funding restricted the program to projects whose outputs – even if industry had been able (financially, managerially, and market-wise) to commercialize them – would have shown only marginal benefits.

The coal-mining industry's problems, though amenable to amelioration through advanced technology, required additional public policy measures, as outlined in Task 4, which were not given the attention they deserved — particularly as seen now, with hindsight, in a time of energy crisis. Even though foreseen by some authorities, political conviction was lacking by Congress and the Executive to place these additional measures on the public policy agenda.

Coal conversion — in the pre-energy crisis period — had very limited federal R&D support. Gasification and liquefaction were of little apparent interest to manufacturers and users of these products. The implications of scale and risk, and other barriers, were not factored into federal R&D planning. If the Interior Department had tried to sell a substantial, objectives-oriented, national-policy-sensitive R&D budget to either the Bureau of the Budget or the Congress, it would have been outside the bounds of credibility and a potential candidate for total rejection.

It took the exigencies of a major national energy crisis to recognize, belatedly, the national significance of coal resources and its conversion products, and to formulate new R&D and additional infrastructure policies.

Therefore, experience with coal extraction and conversion R&D suggests that, absent a national policy on utilization of this national resource, federally-funded R&D at relatively low levels is inefficient in achieving any objective.

C. MOTOR VEHICLE SAFETY

Task 1 — Origin of Civilian R&D Policies

- The federal program in motor vehicle safety research, a recent development in America's automotive history, was undertaken because of the rising toll of death and injury that accompanied the nation's increased use of motor vehicle transport. In the 1950's and 1960's, several agencies of government, including the Congress and certain departments of the executive branch, called attention to the rising tolls and subsequently undertook efforts to show that such losses were preventable.
- The origins of the federal program may be traced to efforts by a few key individuals in Government, most notably Daniel Patrick Moynihan, then Undersecretary of Labor; Kenneth A. Roberts, then representing an Alabama district in the House of Representatives; and Ralph Nader, a consumer advocate whose arguments for safer automobiles sparked the 1965 Senate hearings that led to the National Traffic Safety Act of 1966.
- Initially, responsibility for carrying out the federal R&D program was put in the hands of the Department of Commerce. More recently, it has become the responsibility of the National Highway Traffic Safety Administration in the Department of Transportation. Rulemaking and R&D to support it are both the Administration's responsibilities.

- The program of research is planned in NHTSA to supply the support needed for rulemaking, but funding is reviewed and authorized by the Transportation Branch of the Office of Management and Budget. The R&D program itself is a matter of concern to the oversight committees of Congress.

Task 2 – Explicit and Implicit Policies for Allocating Civilian R&D Funds

- The federal government program of R&D is based on a policy of rapid introduction of *existing* technology.
- The research strategy which derives from such a policy is one which implies that major reductions in accident losses due to improvements in the motor vehicle are not likely and that most of the gains will be made through the use of what is now known to be effective.
- The federal program emphasizes the reduction of human losses in motor vehicle accidents. Efforts are directed at the “second collision” – that of the vehicle occupants with the interior of the vehicle.
- The legislation which launched the federal program mandated a system of safety-related performance standards to be met by motor vehicle manufacturers as the means for forcing the available safety technology into the motor vehicle.
- Research supporting these standards was to be supplied under contract with independent civilian agencies whose efforts were to be directed at specific tasks and whose work was to be accomplished by specific approaches and procedures.
- Because of the emphasis on performance standards and the difficulties of writing such standards, research is directed at components rather than systems. In a larger sense, the system of concern is the total motor vehicle system and its efficiency, economy, and environmental effects, as well as its safety.

Task 3 – Explicit and Implicit Objectives of Civilian R&D Funding

- The 1966 legislation which created the National Highway Safety Bureau and its successor organizations, and which initiated the federal program of motor vehicle safety research, has as its stated objective the reduction of losses in motor vehicle accidents due to deficiencies in the motor vehicle itself.
- The goal of the federal program is the reduction of risk to reasonable levels through a program of “technical forcing.” Such forcing would be accomplished by obliging manufacturers to produce products whose components would meet performance specifications established by research as attainable and cost-effective.

Task 4 -- Alternatives to Civilian R&D Funding

- Alternatives to a federally-funded research and development program, as means for the improvement of motor vehicle safety, are conceivable. Various forms of subsidy, penalty, and information dissemination are available to pursue ends similar to those of the R&D program.
- The economic incentives of subsidy and penalty pose severe administrative difficulties because they are costly or require immense amounts of accident data in order to differentiate risks by make, model, and year of vehicle, and the effectiveness of the various safety items being considered.
- Information dissemination, as a means of inducing demand for vehicle safety improvements, poses other problems in addition. Its effectiveness is markedly limited by individual perceptions of risk and risk acceptance and the prevailing belief that accidents happen only to others.

Task 5 -- Relative Efficiency of Civilian R&D Funding

- The federal program is directed by a single agency (NHTSA) which, in a sense, exercises almost monopsonistic control over the nation's program in motor vehicle safety. This program is designed to support rulemaking for the purposes of forcing available safety technology into the motor vehicle product.
- The program emphasizes existing technology and discounts the possibility of future major gains in safety through research-developed innovations.
- In terms of stated goals, i.e., reduction of losses in motor vehicle accidents, it is not possible to demonstrate conclusively that the program has been effective. It may, in fact, never be possible to isolate with any reasonable certainty the contribution made to reducing accident losses by motor vehicle safety components. Too many factors simultaneously affect the accident rate.
- In terms of the conduct of its program, the efficiency of the research effort is less than could be hoped for. Criticism has been directed at the NHTSA from several quarters for its failure to make use of the research it has bought. Important results are left insufficiently evaluated for early implementation as standards. Frequently, these results are not coordinated within the agency and with other agencies having regulatory concerns with the motor vehicle (FEA and EPA, among others).

D. URBAN MASS TRANSPORTATION

Task 1 -- Origin of R&D Policies

- The policies have originated from different sources over time and have changed significantly in response to administrations, officials, and their political priorities.

- Major explicit policies have different origins than implicit policies.
- Congress has played an intermittent role in shaping R&D policies.
- UMTA Administrators, more than any other parties, have been the source of the crucial implicit and explicit policies.
- The cities and users have had the least consistent influence over policies although most of what has transpired has been justified as aiding them.
- Neither transit operators nor the traditional producers have been the source of major implicit and explicit R&D policies.

Through its authorizing legislation, Congress laid the framework and overall directions for R&D policies by requiring that a study be conducted of transportation R&D needs for program planning purposes. This action under the 1962 Urban Mass Transportation Act was designed to get some policies and priorities considered for R&D rather than reacting to individual requests for demonstration money made by cities.

When urban transportation was the responsibility of the U.S. Department of Housing and Urban Development (HUD) (prior to 1968), it set the following objectives in its "New Systems Study":

- enhance and improve the total city system.
- achieve equality of access to urban educational, job, and cultural opportunities.
- improve the quality of transit services.
- relieve traffic congestion.
- achieve more efficient urban land use.
- provide cleaner, quieter, and more attractive public transportation
- provide more alternatives to urban residents in mode and style of urban living, and
- permit orderly improvement of urgent transportation problems without pre-empting long-range solutions for the future.

Since the R&D has been under Urban Mass Transportation Administration (UMTA), UMTA administrators have been the source of major policies. In reality, this has been shared by the Directors of UMTA's Office of RD&D, who have prepared the major alternatives for

consideration by UMTA administrators. However, certain projects were singled out by UMTA administrators for special treatment and were actually governed by separate policies, in response to pressures by special interest groups.

While most of the major policies have originated with these two positions, the Secretaries of DOT have had a major role in prioritizing different policies and adding authority to different policies. It is evident that, in the period from 1968-1972, many of the federal funding policies were motivated by the goal to produce visible, attractive, dramatic results that would reflect well on the Secretary and the Administration.

The general transit operating and manufacturing industries have not been an origin of major R&D policies. This is due to the conscious decision made at UMTA in 1968 to turn to new sources for solutions to problems. It also can be attributed to the absence of a coordinated, effective body within the transit industry to influence R&D policies. Finally, the transit industry has placed more emphasis upon incremental, service, equipment, maintenance and management improvements. However, during a major part of mass transportation R&D history, substantial R&D funds have been spent on New Systems R&D.

Task 2 – Explicit and Implicit Policies for Allocating Civilian R&D Funds

Explicit

The explicit policies have been relatively consistent throughout the major history of mass transportation R&D. Specifically, they can be characterized as the following:

- Funding of R&D that has the potential of alleviating the problems of the cities.
- Funding of R&D to reduce the costs of mass transportation.
- Funding of R&D that would increase the attractiveness of mass transportation over the automobile for urban travel.
- Funding of R&D that could encourage efficient land use and increase mobility in metropolitan areas.
- Funding of R&D that will develop transit systems which increase accessibility to employment, recreational, and other centers for the entire population at the lowest cost.
- Funding of R&D that would reduce pollution in the urban areas.
- Funding of R&D that has the potential of improving the quality of mass transportation in terms of speed, safety, and aesthetics.

The explicit policies had their roots in the ailing transit systems and problems of the cities. They were based upon the overall goals for mass transportation and mass transit R&D which were required by Congress and formulated in the New Systems Study.

Implicit

Implicit policies have evolved and changed over time, conforming to the contingencies and priorities of different administrations, UMTA policy leaders, short-term national goals, and political incentives. They have changed in terms of substance, emphasis, and interpretation. Specifically, the following objectives have been associated with different eras:

Before 1968 at U.S. Department of Housing and Urban Development (HUD)

- Funding on reactive basis based upon requests made by cities.
- Funding of demonstrations that would build a constituency for UMTA.
- Funding R&D in the name of demonstration programs.

1968 – 1972 DOT/UMTA)

- Funding of R&D that involved aerospace technology industry, expertise, and technicians.
- Funding of R&D that would provide the most immediate, visible, and newsworthy payoff.
- Funding of hardware and technological alternatives for improving mass transportation.
- Funding of R&D that would divorce mass transportation from traditional and conventional ideas, manufacturers, approaches, and interests.
- Funding of New Systems R&D

1972 – Present (DOT/UMTA)

- Reduction of R&D funding for hardware, new systems solutions.
- Funding of R&D directed toward specific, verifiable, metropolitan needs and demands.
- Funding R&D that will produce low-cost alternatives for the improvements of mass transportation.

Task 3 – Explicit and Implicit Objectives of Civilian R&D Funding

Explicit

The explicit objectives, like the explicit policies, have been relatively permanent over time. They were based on Congressional legislation that authorized the program and the New Systems Study which was mandated by Congress for the expressed purpose of setting guidelines for future mass transportation R&D.

Specifically, the explicit objectives have been to:

- demonstrate new ideas and to build knowledge through risk money.
- relate mass transportation to the national objectives of rebuilding the nation's cities.
- create equality of access.
- link mass transportation R&D to land use and to address both institutional and technological problems.
- produce quality of transit service.
- relieve traffic congestion.
- minimize adverse impact on the environment.
- enhance efficiency of equipment and facilities.
- categorize, conceptualize, and develop prototypes of the state-of-the-art.
- trigger innovation in terms of aesthetics, speed, reduced pollution, comfort, and safety.
- increase ridership.
- demonstrate life cycle costs and prudent risks.
- help disadvantaged riders, such as the elderly and handicapped.
- produce energy-saving technology.

Implicit

The implicit objectives have changed over time in response to the change in Administrations and chief R&D policy-makers. They have been:

1962 -- 1966 (HUD)

- to build the confidence of the transit industry in the federal government and to establish a city constituency.
- to save the northeast commuter railroads.

1966 -- 1968 (DOT/UMTA)

- to define need, constituency, and technical approaches that responded to problems of the cities.

1968 -- 1972 (DOT/UMTA)

- to use the expertise and manpower of aerospace to build technological advancement in mass transportation.
- to shore up the stagnant transit industry and to project the industry into the modern age of high technology.
- to increase standardization.
- to produce products that were tangible, visible, salable, and politically beneficial.
- to bail out promising demonstrations that were floundering.
- to stimulate technological advances that would be replicated.
- to terminate the federal purchase of obsolete equipment being purchased under the capital grants program.
- to develop the government information base for setting product specifications based upon newer technology, e.g., the TRANSBUS prototype.
- to increase competition in the production of mass transportation equipment.
- to reduce pollution.

1973 - Present

- to place increased emphasis on mass transportation management operations, and service improvements.
- to terminate R&D funding after the prototype development stage and let industry continue development to the production stage.
- to fund "high risk-high payoff" R&D, such as the continuing work on PRT.
- to protect the federal government's investment in existing transit equipment.
- to make the market the driving force for R&D, not the technology.

Task 4 - Alternatives to Civilian R&D Funding

There is no feasible alternative to federal R&D funding to produce major mass transportation technology changes such as the development of new systems. Private industry is both unable and unwilling to make the large investments required for the following reasons:

- the absence of a predictable, long-term market for their product.
- domination of the metropolitan area market by the federal government, combined with the fears of whether the federal government will continue to support qualifying products.
- high costs of the R&D.
- low-volume market for new systems products.

Metropolitan areas are unable or unwilling to fund new systems R&D for the following reasons:

- lack of funds to undertake the R&D.
- lack of technical skill to supervise the R&D.
- unwillingness to assume R&D costs out of local budgets to meet nationwide transportation needs.
- uncertainty that any manufacturers would bid, given the market uncertainty and high risks.

- unwillingness to take political risk of failure of the technology.

For these reasons, the federal government is the only source with the opportunity, power, and resources to fund new systems R&D.

Alternatives to exclusive federal R&D funding exist to stimulate incremental product improvement, vehicle improvement, small component development, or service innovations.

Task 5 – Relative Efficiency of Civilian R&D Funding

Experience to date suggests that federal R&D funding has been inefficient in achieving the major objectives established for the program. However, this conclusion must be tempered and understood in light of the following facts: (1) many of the projects launched are still incomplete, or their products have not been in existence sufficient time to realize their full potential impact; (2) no clear alternatives different from federal R&D funding have been discovered to accomplish the program objectives, given the special conditions and needs of mass transportation; and (3) past experience has illustrated that policy-makers were too sanguine about prospects for improvement, given the complex conditions of the transit industry, metropolitan government decision-making, the federal government's ability to manage and direct R&D, and the non-technical problems peculiar to mass transportation.

We conclude that the relative efficiency of federal R&D funding in urban mass transportation was impaired by:

- frequent policy and administrative changes in DOT/UMTA.
- political pressures which distorted realistic goals and time frames for selected R&D projects.
- lack of attractive market incentives to encourage manufacturers to commercialize the products of R&D.
- conflicting policies within DOT/UMTA adversely affecting market opportunities.
- failure to pay serious and continuing attention to user needs and priorities.
- lack of a national transportation policy, particularly as to personal transportation in cities.
- relatively low level of technical expertise available in UMTA for directing and managing the R&D programs.

- inappropriate qualifications of major R&D performers.
- lack of long-range planning and assured continuity of federal funding.

E. FOOD PROCESSING: SOYBEAN

Task 1 – Origin of R&D Policies

- Agricultural R&D policy originates with the U.S. Department of Agriculture (USDA); technical input comes from USDA's Agricultural Research Service (ARS).
- USDA R&D policy reflects major farm problems and is primarily concerned with support for the farmer; especially, farmers engaged in the production of the heretofore surplus commodities -- cotton, corn, and wheat.
- As a consequence of edible soy-protein's potential as a meat replacement, and the value of soybean meal as an inexpensive animal feed, organized trade group and industry pressure for a national vegetable-protein development policy has been minimal.

Task 2 – Explicit and Implicit Policies for Allocating Civilian R&D Funds

Explicit

- To increase soybean yields through development of improved plant varieties.
- To increase soybean yields through development of more effective pesticides.
- Utilization of R&D to protect established markets for the processed soybean products: oil, and meal.
- To develop edible soy protein to meet the critical international and growing domestic need for increased supplies of inexpensive, high-quality protein.

Implicit

- Not to antagonize those presently vested interests, such as the livestock growers, who are basically antagonistic to the development of edible soy protein.
- To preserve the soybean's proportionate funding allocation in balance with the other regions, commodities, and needs, competing for funds.

- To favor R&D projects having low risk, short-term payout, with high constituent visibility.

Task 3 – Explicit and Implicit Objectives of Civilian R&D Funding

Explicit

- Agricultural R&D objectives exist in two broad categories, farm production and commodity utilization.
- With respect to soybeans generally, and edible soy-protein specifically, these objectives are integrated into the missions of the USDA's Agricultural Research Service. They are consistent with USDA's broad agricultural R&D policy.
- The primary objective of soybean R&D has been to solve problems affecting farm production. The two objectives derived from this primary are: to improve soybean yield per acre, and to minimize pest- and disease-caused crop losses.
- Soybean-utilization R&D objectives focused primarily on soy oil for industrial and edible applications, and soybean meal as an animal feed. Efforts were designed to protect and expand existing markets for these products.
- For the most part, the objective of soybean meal R&D was to increase its value and utilization as an animal feed.
- To develop basic knowledge of the chemical, physical, and physiological properties of soy-protein.

Implicit

- To conduct basic research upon which industry may draw, but not to directly subsidize industrial R&D.
- To disrupt the continuum of effort as little as possible from year to year, in order to maintain the delicate balancing of interests.

Task 4 – Alternatives to Civilian R&D Funding

Alternative measures, capable of inducing technical efforts in the industrial sector to develop (and commercialize) edible soy-protein, relate to market stimulation:

- Using the School Lunch Program to stimulate demand.
- Using PL 480 as a vehicle for international distribution of sophisticated edible soy-protein forms.

- Revising Food and Drug Administration (FDA) labelling regulations to promote positive image in the retail marketplace.

Task 5 – Relative Efficiency of Civilian R&D Funding

The federal commitment to the objective of developing edible soy-protein science and technology was minimal with respect to anticipated future protein needs.

Experience with federal funding R&D on soy protein suggests that, particularly when it is restricted to basic and exploratory research, the results are ineffective in a situation where the subject as a whole is receiving low priority by the funding agency. The work is primarily of professional interest to the scientists in the agency's own laboratories and has little relevance to the potential interests of industry.

Therefore, if a significant social goal is to be achieved (i.e., improved nutrition), Congressional and Executive support must be obtained on the priority and level of support to be given. In this case, political pressures produced an ambiguous situation, and led to programs being pursued mainly for their own scientific sake.

In only one instance (school lunch programs), it became evident that additional public policy measures (i.e., market stimulation in this case) led to significant product R&D being funded by private sources in order to capture significant portions of this substantial market for soy-protein.

F. BIOLOGICAL PESTICIDES

Task 1 – Origin of R&D Policies

- The Agricultural Research Service (ARS) of the U.S. Department of Agriculture (USDA) and State Experimental Stations through Hatch Act/CSRS are principal initiators and funders of R&D.
- U.S. Department of Agriculture (USDA)/Forest Service; The Center for Disease Control (CDC) of the U.S. Department of Health, Education and Welfare (HEW) and National Institute of Health (NIH); National Science Foundation (NSF); Environmental Protection Agency (EPA); U.S. Department of Interior (DOI) are additional funders of R&D.
- No coordination between these agencies, nor even between components of U.S. Department of Agriculture.

Characteristics

- Commercialization of R&D never an explicit goal.
- User (farmer) has available economic pest control alternatives and does not perceive need for biological controls.
- Industry (manufacturer) does not see adequate market and/or profitability -- instead problems of use, user education, and costs and compatibility with current chemical pesticide industry.
- Congressional and Executive interest increased after *Silent Spring*, NEPA, and FEPCA, but traditionally has been low level.
- There is a general mandate in several laws for USDA to conduct research on subjects related to agriculture. Biological pest control is subsumed under this but not specifically emphasized.

Task 2 – Explicit and Implicit Policies for Allocating Civilian R&D Funds

Explicit

- Rely heavily on key individual research scientists to suggest and develop research directions, with increasing inputs from outside groups such as universities and state agricultural staff.
- Within ARS, increased current decentralization of funding policies to regional, institute, and laboratory levels in contrast with prior centralization in Entomology Division.
- In-house performers for ARS and Forest Service funding.
- Land grant universities major performers for CSRS funding, with director of state experiment station establishing funding policy (Hatch Act funds).
- Almost no industry performance of federally-funded R&D; up to 1960 no contract authority, and only few industrial entities available to perform research.
- Little Congressional or Executive influence on funding allocations, except for establishment of research centers in politically important states.

Implicit

- Policies for basic research are characterized by long-term academic research, comprised of broad spectrum of narrowly-focused projects.
- Policies are oriented toward continuous funding of existing established centers and individual researchers.

Characteristics

- Within the U.S. Department of Agriculture, research policy has emphasized both basic long-term research on biological pest control mechanisms and techniques, and applied research and development, including field testing, on specific pests and crops of regional or local importance. Although the research has emphasized some of the needs of the pest control and agricultural industry, and the individual consumer (farmer), it has not resulted in the widespread availability and applicability of biological control techniques.
- Funding to answer questions of technical feasibility.
- Funding to advance the state of technology.

Priority Ranking of Characteristics (in order of highest priority)

- Open-ended, multi-year funding.
- Funding for basic research and knowledge.
- Funding to advance the state of technology.
- Funding as a catalyst for technological change.
- Funding to answer questions of technical feasibility.
- Funding on a demonstration scale.
- Funding to compensate for gaps in civilian R&D.
- Funding to create a manpower pipeline for R&D.

Task 3 – Explicit and Implicit Objectives of Civilian R&D Funding

Explicit

- Increase basic knowledge of biological control techniques.
- Develop and test experimentally biological control techniques that can be used against specific target crop and insect pests of economic agricultural (and health) significance throughout the U.S.
- Reduce dependence on traditional pesticides and develop environmentally safe methods.
- Provide for training of scientists in plant pathology, entomology, agronomy, and related fields.

Implicit

- Contribute to current level of basic knowledge on plant and insect physiology that may be of long-term benefit to agriculture, i.e., pump-priming of a neglected but needed field of R&D.
- Maintain centers of knowledge and expertise for readiness in times of agricultural crises or pest epidemics.
- Commercialization of biological control techniques has not, by itself, been a major goal.

Task 4 – Alternatives to Civilian R&D Funding

Alternatives to accomplishing the objectives of ARS and other agencies in biological control are:

- Interagency coordination of biological pesticides R&D— such as the Huffaker program.
- Giving consideration to a single coordinated, organized federal research program.

Alternatives to aid the commercialization of biological pest control methods include:

- Make eventual commercialization of biological control approaches a recognized goal of ARS, CSRS, and other federal programs.

- Research and implementation of major Integrated Pest Management Programs, using both biological and chemical methods in appropriate combinations.

Within this context, the following alternatives to direct federal funding of R&D may be applicable (given in order of priority):

- Royalty incentives — providing some means of patent or license protection.
- Regulatory incentives aimed at making biological controls "easier to register" with EPA.
- Risk guarantees — both financial and to the user to encourage development and use.
- Low interest venture capital availability and cost sharing would interest smaller companies but not large established entities.

Task 5 — Relative Efficiency of Civilian R&D Funding

Experience with federal funding of R&D in this area showed that it has not been effective in establishing the widespread use of biological control techniques in U.S. agriculture. However, end use of biological controls was not a specific research objective, and R&D funding was dispersed among many uncoordinated agency programs.

Basic knowledge has been significantly advanced through federal R&D funding. A basis for future work, both information and trained personnel, has been established. Specific, selected demonstrations of biological controls have been successful (e.g., screw worm eradication in the Southeast to facilitate cattle raising). In general, though, the user (farmer) and manufacturer are disinclined to accept the risks of using such controls because of greater cost, inconvenience, major operational changes needed to achieve successful results, lack of economic advantages compared to chemical controls, both from the viewpoint of the user and manufacturer.

The Integrated Pest Management Programs recently begun show desirable features of combining civilian R&D funding with other public policy measures that may help overcome some of the barriers to commercializing the use of some biological control methods.

Therefore, additional public policy measures, as indicated in Task 4, need to be introduced if the use of biological controls is to be made commercially attractive. Without them, the availability of those existing chemical methods that are still federally approved will inhibit commercialization of biological controls. An Integrated Pest Management Program seems to be the most promising route to take.

APPENDIX A

LIST OF STUDY PARTICIPANTS

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PROJECT MANAGEMENT

- Michael Michaelis (Deputy Project Director – July 1974-December 1974
Project Director – January 1975-December 1975)
- William D. Carey (Project Director – July 1974-December 1974)
- Charles J. Kensler (Chairman, Project Review)
- Peter G. Gerstberger (Sector-Team Coordinator)

SECTOR TEAMS

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- Robert J. McWhorter
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COAL EXTRACTION AND CONVERSION

- Stanley V. Margolin (Team Leader)
- Henry E. Haley
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MOTOR VEHICLE SAFETY

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